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Advancing optimization state-of-the-art and moving it into engineering practice

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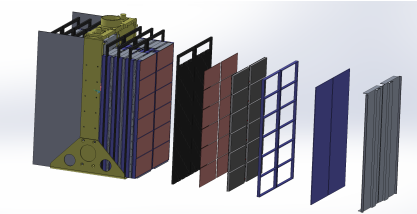
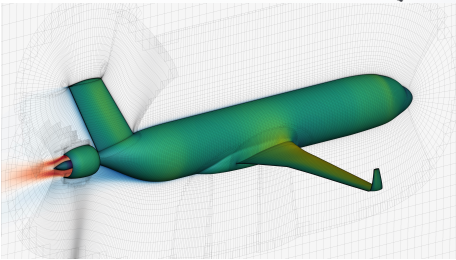
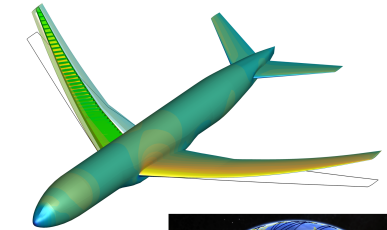
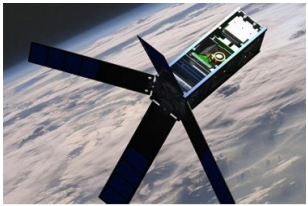
Multidisciplinary **D**esign **A**nalysis and **O**ptimization

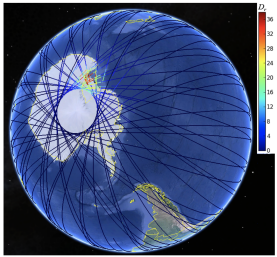
Complex, highly coupled systems are everywhere: airframes, air traffic control, custom tailored materials, battery packs, cubesats, wind turbines



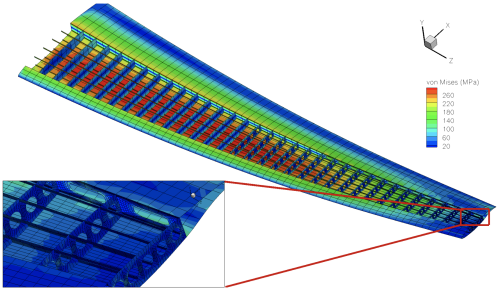




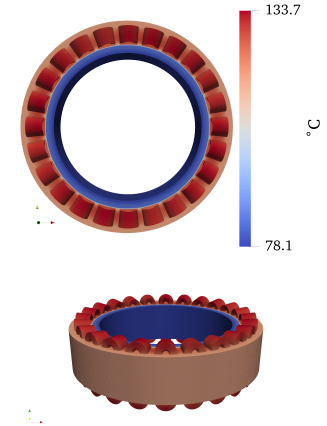




Desinging these systems often requires high-order analyses like CFD and FEA.

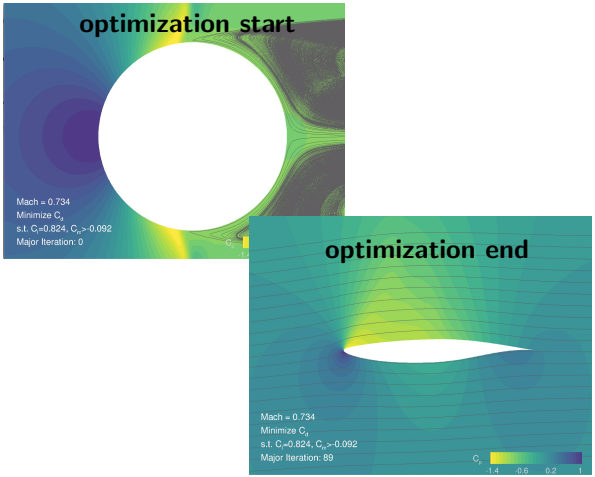


"A parallel aerostructural optimization framework for aircraft design studies", G. J. Kennedy, and J. R. R. A. Martins. Structural and Multidisciplinary Optimization, 50(6):1079–1101, 2014



"Multidisciplinary Analysis of Propulsive Electric Motors During Takeoff", T. Babcock, G. Bedonian and J. E. Hicken, AIAA Scitech 2021 Forum

High order tools are very sensitive to geometry; optimization with analytic derivatives finds useful geometry for analysis



- 10x-10,000x faster than other methods and scalable to 1,000,000s of design variables
- Analytic derivatives are needed to make this computationally efficient
- The MDO community has refined this method for higher order tools. Many open source options are available with derivatives

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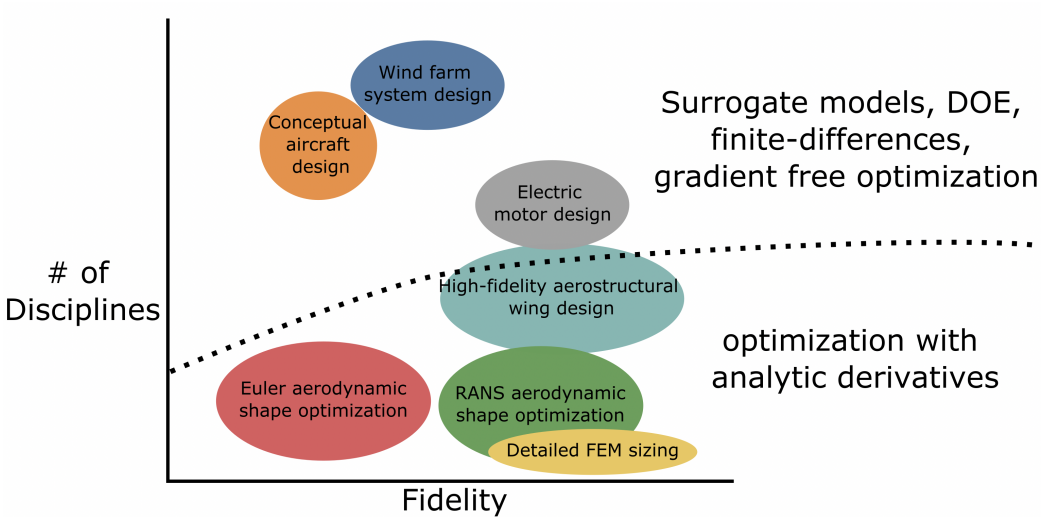
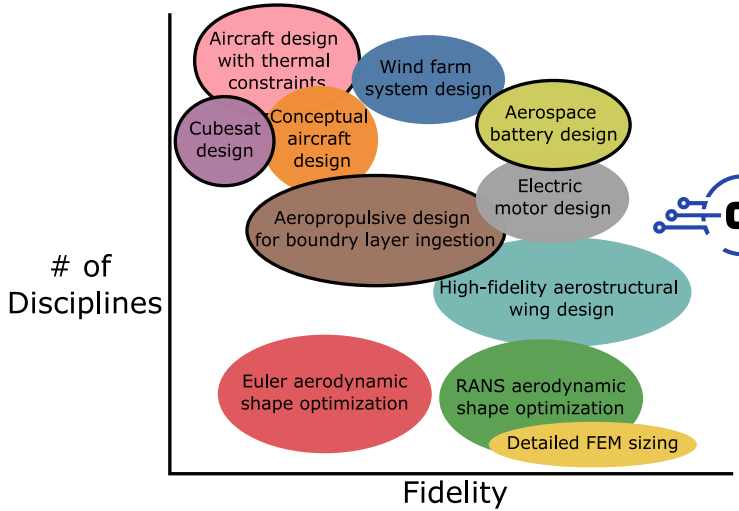
"Robust aerodynamic shape optimization - From a Circle to an Airfoil" He, Li, Mader, Yildirim, Martins, Aerospace Science and Technology, 2019

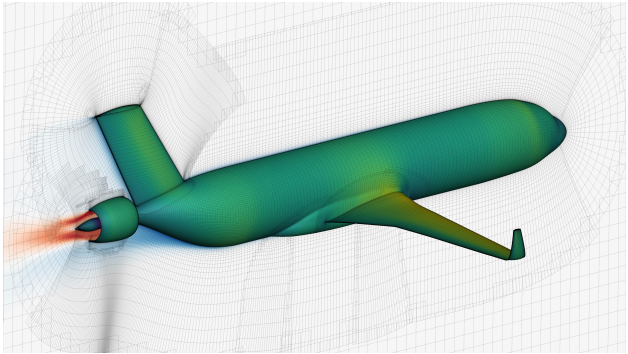
Complex and highly coupled systems require a mix of low-order and high-order analyses, but there is problematic methods gap

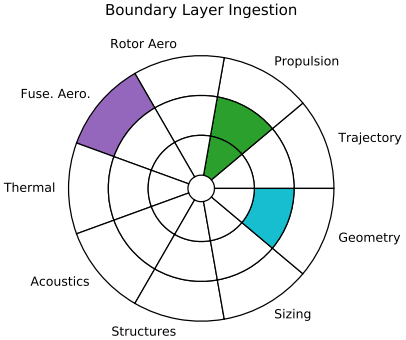


OpenMDAO eliminates the methods gap, enabling design optimization with any method and any mix of low- and high-order analyses

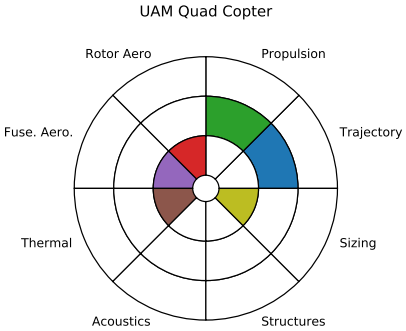


Example: Aeropropulsive design of the BLI thruster on STARC-ABL using VSPAero geometry, RANS aerodyanmics, and mixed fidelity propulsion

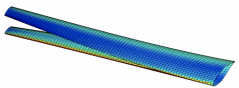




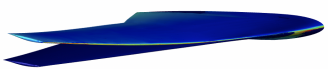
Example: Tight trajectory-thermal coupling captures critical sizing conditions for electric aircraft propulsion design



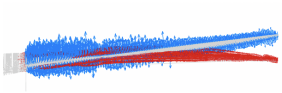
Example: High fidelity aerostructural analysis and optimization with swappable solvers



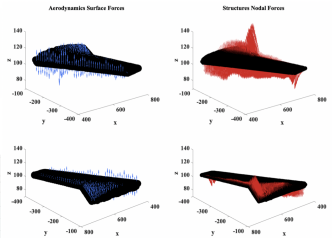
VLM+MELD+TACS



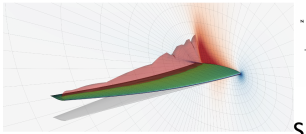
FUN3D-SFE+MELD+TACS



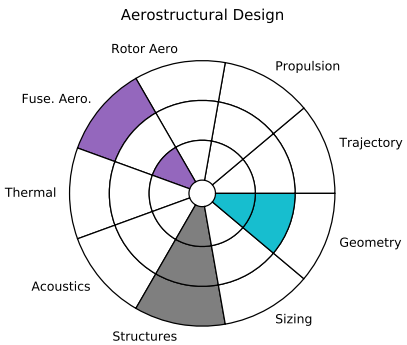
SU2+MELD+TACS (Stanford)



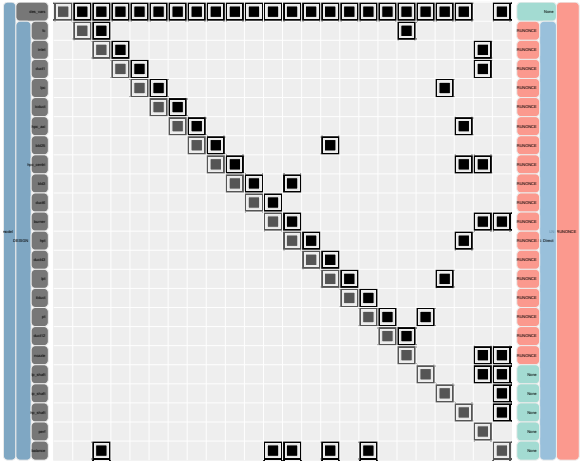
SU2+MELD+NASTRAN (Stanford)



ADFlow+RLT+TACS (Michigan)

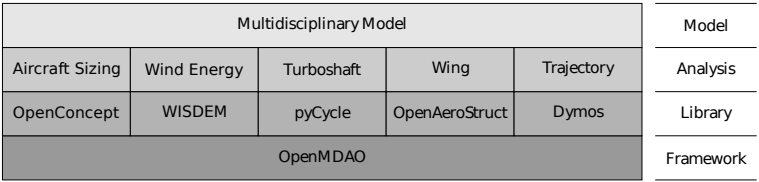


OpenMDAO provides interactive model visualziation tools to navigate the large, complex system models



The N2 visualization tool shows all critical elements of an OpenMDAO model in one dynamic and interactive diagram

OpenMDAO is more than just a framework for integrating existing analysis tools. It is also a platform for building new ones



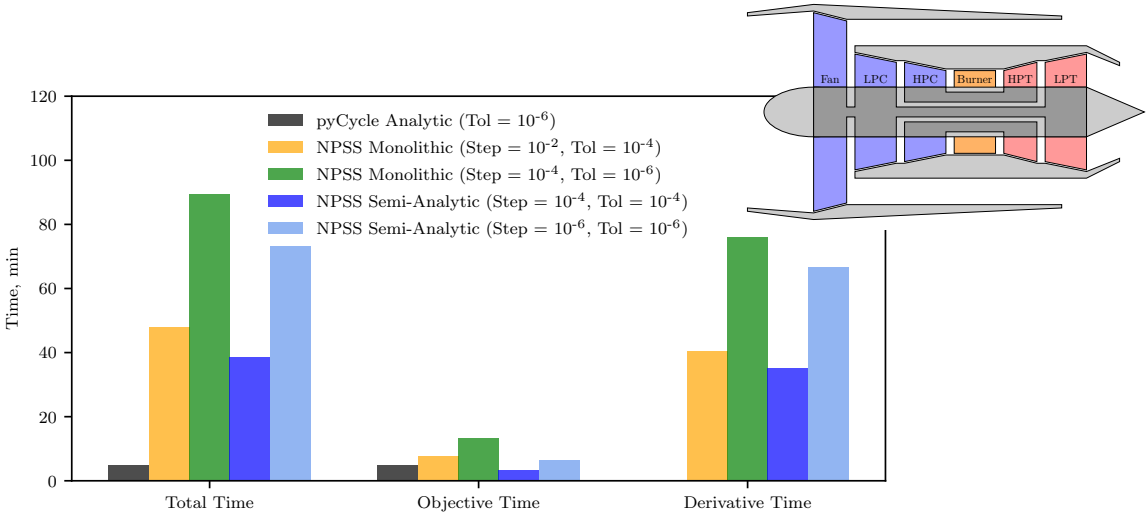
NASA

- **pyCycle**: propulsion system design
- **Dymos**: general optimal-control

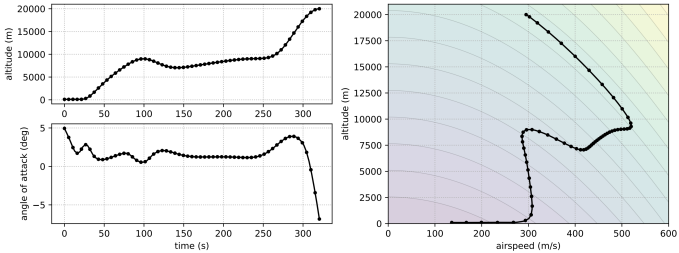
External

- **OpenAeroStruct**: low fidelity aerostructural design
- **Open Concep**t: conceptual aircraft design
- **WISDEM**: Wind farm design
- **OpenMDAO.jl**: Code OpenMDAO in Julia
- **WhatsOpt**: Graphical interface for model building

Design optimization of a high bypass turbofan with pyCycle is 15x faster than industry standard NPSS

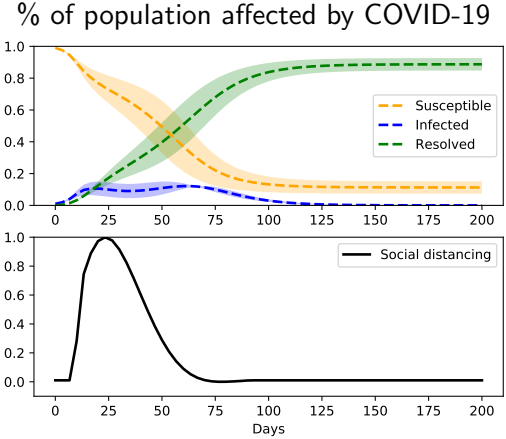


Dymos combines design optimization with time-dependent optimal control problems and analytic derivatives



- open source: https://github.com/openmdao/dy
- Bryson's min-time-to-climb example faster than legacy fortran tools
- Critical library for modeling thermal transients in aircraft missions

OpenMDAO + Dymos is extremely flexible.
COVID-19 optimizations to study the effects of social distancing



This model considers the uncertainty around the transmission and death rates of COVID-19 to predict a social distancing policy that minimized the overall uncertainty

OpenMDAO has a broad, international external user community industry, academia, government labs

- National Renewable Energy Lab + DOE: Wind Farm Design
- Air Force Research Lab + Northrop Grumman: Aerostructural and aeropropulsive design optimization
- Uber Elevate and Lillium aircraft: eVTOL
- ONERA: Aircraft and spacecraft design
- Aurora Flight Sciences: Aerostructural aircraft wing design
- Raytheon: Missile design
- Georgia Tech Research Institute+DOD: Model based systems engineering
- Academics: Georgia Tech, University of Michigan, Stanford, MIT, RPI, Purdue, BYU, Supaero, UC San Diego, DTU

OpenMDAO, pyCycle, and Dymos are all open source!

What is stopping you from getting 15x faster analyses?

J. S. Gray, J. T. Hwang, J. R. R. A. Martins, K. T. Moore, and B. A. Naylor, "OpenMDAO: An Open-Source Framework for Multidisciplinary Design, Analysis, and Optimization," Structural and Multidisciplinary Optimization, 2019.